A GENERAL PHYSIOLOGY

FOR HIGH SCHOOLS

BASED UPON THE NERVOUS SYSTEM

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BY

M. L. MACY, L.B.

ASSISTED BY

H. W. NORRIS, A.M.

PROFESSOR OF BIOLOGY, IOWA COLLEGE

"*The physiology of the nervous system is emphatically the physiology of the future.*" — MICHAEL FOSTER, M.D., F.R.S.

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PREFACE

The effort has been made in this book to unify the study of the parts and the functions of the human organism by the application of approved pedagogical and scientific principles. The teaching of any science proceeds logically from that which is known to that which is not known. Physiology is one of the earliest of the natural sciences to be presented for formal study in school. In respect to man's organism the one sort of knowledge absolutely original and elemental is *consciousness* — conscious motion and sensation. This it is that forms the most apparent difference between the two kingdoms which manifest the phenomena of life. It is characteristic of animals to possess consciousness, volition, feeling. Plants are, to all appearance, devoid of them all.

Hence this study of human physiology is made to begin with that part of the body which is the organ of consciousness — the *nervous system.* The pupil knows that he thinks and feels and wills and moves, and he studies physiology in order to understand the apparatus by which these wonders are accomplished. He is here given first (after a few preliminary definitions) a brief sketch of the parts composing the nervous system. Next he studies those physical operations into which consciousness enters as an essential quality, and becomes familiar with the organs of motion and sensation. This leads naturally to consideration of the provision for the sustenance of those organs — nutrition in its comprehensive sense. Finally the student comes to a more detailed examination of the mechanism for the conscious activities of the human being.

Whatever may be true of philosophers, the infant begins the study of physiology at the point here suggested, and follows a method in harmony with this plan. More than one practical teacher has worked out a similar method through years of experience in the class room. By making the nervous system (the center and core of all animal life) the leading thought throughout, a unity of impression is secured,

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the actual connection of every vital process with the one nervous system becomes obvious, and the emphasis is placed where it properly belongs. It is believed that this plan has advantages also for the student of general biology. It emphasizes the one grand, obvious distinction between plants and animals. To students of psychology it will likewise commend itself. Because of prevalent ignorance of the nervous system and its due predominance in the animal economy, psychologists have been forced to become physiologists in order to build across the gap, left by the ordinary manner of treatment, between physiology and psychology.

Care has been taken to make no statements not in accord with established science, but no effort is made to introduce the newest conjectures. The necessary limitations of a school text-book have been kept in mind as well as the degree of mental development of those for whom the work is designed.

It is believed that the instruction respecting alcoholic drinks and narcotics, while complying with the requirements of recent legislation in the various states, will be found to be based upon rational and scientific principles, and to be placed before the student in a manner to win the assent of his reason rather than to create a mere prejudice which further knowledge might overthrow. Nothing is gained by overstatement, and it is always safe to tell the simple truth, for nothing will so surely foster right living as a knowledge of the truth.

The writer has had much assistance from experienced and competent teachers and physicians. Dr. A. W. Alvord (M.D., University of Michigan) of Battle Creek, Michigan, has kindly revised the hygienic portions of the book. Mr. H. W. Norris, A.M., Professor of Biology in Iowa College, has read and criticised the whole of the manuscript. All of the experimental work has been prepared by him and will be found of especial value. Many of the illustrations used are such as are commonly found in schoolbooks treating the subject of physiology, but a large number have been adapted from cuts in recent advanced works, mainly those by Morris, Spalteholz, and Van Gehuchten; while numerous other drawings expressly for this work have been made by Mr. E. W. Atherton under the direction of Professor Norris.

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PART I

INTRODUCTION

It is customary to divide the study of the human body into three departments: (1) *Anatomy*, which is the science that describes the structure of the body; (2) *Physiology*, or the science of the functions, or uses, of the various parts of the body, and (3) *Hygiene*, or the science of health, which treats of the care of the body and all its parts for the purpose of maintaining the whole in its best condition for usefulness and enjoyment. The term *Physiology*, as applied to a schoolbook, however, is often used to include all three of these lines of study.

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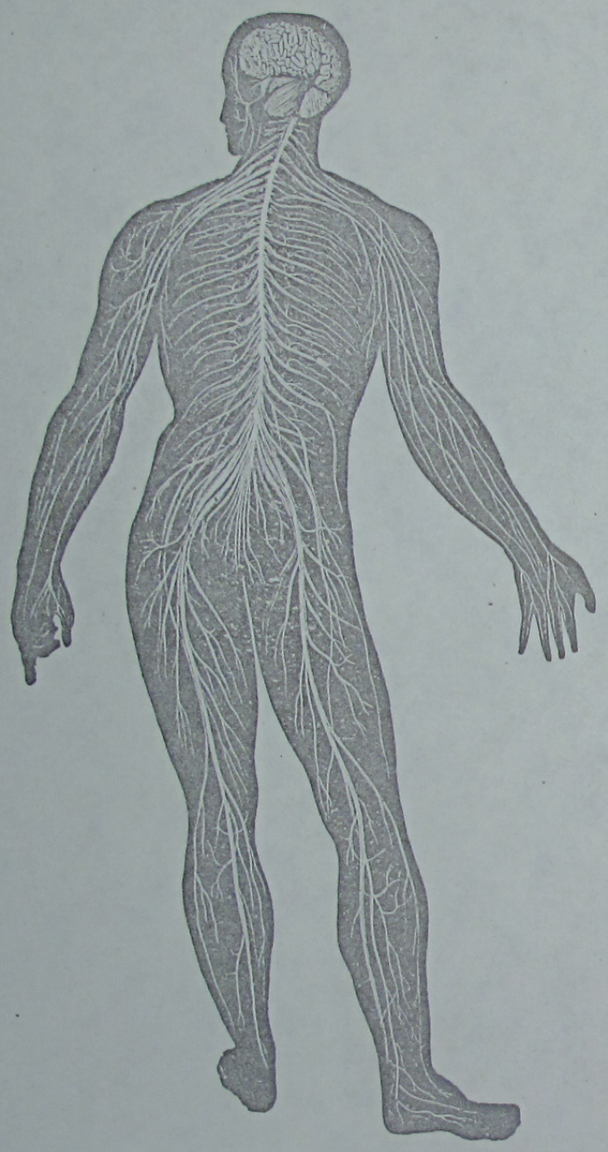

Fig. 1. — The nervous system.

CHAPTER I

MATTER AND CELLS

1. Living and Lifeless Matter. — What matter is we are not yet able to say, but as it exists in our world it may be separated into two great divisions, — living matter and lifeless matter. So far as present knowledge goes, these two sorts of matter are wholly distinct the one from the other, and lifeless matter never becomes living matter except under the influence of matter already living. The same substances are indeed found in the two sorts of matter, and when living matter is killed, or becomes lifeless, no change can be discovered in its weight. That mysterious something called *life* is therefore not material, and living matter may be said to be only ordinary lifeless matter existing in a different state or condition.

2. Chemical Elements. — A substance which cannot be divided into two or more different kinds of matter is called a *chemical element*, or a simple substance. All others are called compound substances. Matter is separated into its elements by processes which affect the molecules or the atoms of which it is composed, that is, by chemical analysis.

A *molecule* may be defined as the smallest particle of matter which exists alone and retains most of the properties of the mass of the substance. An *atom* is one of the ultimate particles of which a molecule is composed. The

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constantly cause pressure upon the tissues and so force the lymph onward in the vessels, the valves preventing any return.

344. Assimilation. — Though the food has been masticated, digested, and absorbed, it has not yet nourished the body. Still another process is needful before the new material becomes part of the continually wasting tissues. That process is called *assimilation*, and, though we cannot pretend to understand it, it may be described as the action of the living cells in choosing, appropriating, and building into their own substance the suitable elements in the food-laden fluid which comes to them from the alimentary canal and from the lungs.

Correlative to the process of assimilation is the destructive process by which the cells, by combustion and other chemical changes, break up and send out as waste the substances of their structure, to be expelled from the body as *excretions*.

345. Hunger and Thirst. — We associate our feelings of *thirst* with a dryness of the mucous membrane of the mouth and throat, and we say our throats are "parched" when we are very thirsty. But under ordinary circumstances the feeling of thirst arises from a general condition of the system, in which the throat shares, due to a lack of water in the blood, or rather in the lymph. Thirst may be temporarily relieved by moistening the mucous membrane of the soft palate. Hence follows the inference that the afferent nervous impulses originate there, and are caused by a too great removal of water from the lymph of the investing membrane.

Hunger is referred in our consciousness to the particular locality of the stomach, and that organ seems to us to be empty when we are hungry. Indigestible material introduced into the stomach may for a time relieve the hunger, as will a very small quantity of food. The special sensation of hunger appears to be connected with the state of the lining membrane of the stomach, while it must be ascribed in a more general sense to a deficiency of nutrient matter in the blood. Hunger may be alleviated by the introduction of soluble food into the circulation, through the rectum, or through the absorbents of the skin, but the relief comes more slowly thus than through the stomach.

The nervous path of hunger sensations has not been made out. The vagus is regarded as the sensory nerve of the stomach, but it is said that both vagus nerves may be cut and the sensation of hunger be unaffected. The brain centers for thirst and hunger are believed to be in the occipital lobes of the cortex, but they have not been definitely located.

346. Some Practical Points connected with Nutrition. — In order that the first of the digestive operations may be properly performed, it is necessary to have *a good set of teeth* and to *chew thoroughly* the food taken into the mouth. The intensely hard enamel covering the exposed portion of the teeth is a full protection to them against all dangers under proper conditions of life, and under such conditions the teeth would last while life lasts. That this is true is shown by the fact that nature makes no provision for restoring or improving the enamel after it is once formed. Here alone the special cells, whose office it is to form the peculiar substance, entirely disappear when their work is once completed. In all the other tissues these formative cells remain to continue the nutrition and repair of the tissues. But the tooth enamel, whose growth, except in the wisdom teeth, is complete

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when a child is ten or eleven years old, cannot be renewed or improved after that time. It is therefore of the utmost importance that young children should be fed upon food which will build up perfect teeth. Milk should be largely relied upon for the first three years, the diet to be varied during the third and after years in accordance with suggestions given in the chapter on Food. Great care should be taken to guard children against attacks of what are known as "infantile diseases," — measles, whooping cough, etc., which sometimes suddenly arrest or disturb the general nutrition, and especially that of the teeth, so that the enamel becomes rough and irregular, and the teeth are exposed to early decay. Another point should receive special attention. It is observed that young children who live a life of excessive nervous activity, with overstimulation of the brain, are particularly liable to defective development of the enamel of the teeth. This is one among many reasons which make imperative a quiet, regular life for children, without excitement and without undue mental activity.

347. But even perfect teeth may be injured by certain bacteria, which multiply in the decaying particles of food allowed to remain in the mouth. These minute organisms form a corrosive acid which destroys the enamel and breaks down the tooth substance. If the teeth are perfect and are always kept perfectly clean, they will not decay. They should be thoroughly brushed — the upper teeth downward, the lower ones upward — after each meal, and a thread of soft untwisted silk floss or fine strips of rubber should be drawn back and forth between the teeth to cleanse those parts which a brush cannot reach. In brushing the teeth a powder or liquid should be used which contains some safe germicide, — which is a substance destructive to

the microörganisms mentioned above, — and the mouth should be well rinsed with a solution of the same.

348. It is a mistake to suppose that a child should be supplied with soft, pulpy food. Just as soon as the first set of teeth are in place, he should have a fare which will require vigorous mastication. He should not be allowed to reject bread crusts and eat only the soft crumb, nor should his bread be always soaked in milk or gravy. Plenty of hard "chewing" is not only good for the teeth; it also promotes the flow of the saliva necessary to digestion and aids in the development of the jaws, and so helps to provide room for the second set.

The teeth should be under the care of a competent dentist, who by yearly or semiyearly examination and repair will be able to forestall and prevent the inroads of decay.

349. While a due action of the mechanism of mastication is to be sought, that overactivity which results from the *habit of chewing tobacco or gum* is to be avoided. While a sense of propriety and good taste should alone be sufficient to condemn such a habit, there are hygienic reasons for its avoidance. The constant stimulation of the salivary glands leads finally to their weakness and defective action, thus laying a foundation for general derangement of digestion. Many dentists also regard it as directly injurious to the teeth.

350. Food is not ready for the action of the gastric juice until it has been finely divided by the teeth and all portions well moistened with saliva. Slow and thorough *mastication* is therefore necessary to perfect digestion. Too rapid eating not only shows bad manners, but also is exceedingly bad for the health.

351. The *temperature of our food* should not be so hot as to stimulate unduly the glands of the mucous mem-

brane of mouth and stomach, nor so cold as to retard the digestive processes, which normally require a temperature of about 100° F. (38° C.). Ice water should never be drunk, both because of the impurities usually found in the ice, and because its coldness is injurious to the stomach. Very large quantities of any liquid taken with the food may dilute the gastric juice so much as to delay digestion and weaken the organs.

352. It is well to establish and adhere to *regular hours for meals*. The intervals between meals should be long enough to permit the digestive organs to rest between their periods of activity, and fresh food should not be taken into the stomach to mix with that partly digested; that is, "eating between meals" is to be avoided. A habit of continually nibbling at dainties is extremely pernicious, and may give rise to serious and perhaps incurable disease.

353. A considerable *variety in diet* is wholesome, but as a rule one should adhere to the simpler and more easily digested kinds of food. A person in health is scarcely conscious of possessing a stomach, but injudicious indulgence may so disorder the natural processes that they will be constantly attended with discomfort or suffering.

354. It is impossible to prescribe definite rules for the *quantity of food* to be taken daily. A strictly natural appetite is undoubtedly a safe guide; but appetite is so often and so early perverted that it is seldom reliable. Food enough must be taken to supply the daily waste of tissues. Continuous loss of weight is usually a seriously unfavorable symptom. During the natural period of growth the amount of food must be sufficient to supply also what is needed for the full development of the body. One living a life of physical activity requires, as a rule,

more food than one engaged in sedentary occupations. Brain workers, however, need a varied and generous diet, and along with it great care should be taken to secure sufficient outdoor exercise. More food is called for in winter than in summer, and more of the carbohydrates to supply the demand for additional heat. Those who work vigorously in the open air, and especially in cold climates, often consume prodigious quantities of fats without injury to digestion. With the coming of old age the vital processes in general are carried on more slowly; digestion and especially the power of assimilation are enfeebled. Less energy is called for as the activities are lessened, and less food is then required, with longer intervals between meals. Foods rich in proteids are less needful and should be diminished in quantity, while those which yield a large amount of heat should be substituted.

355. **What is Alcohol?** — All organic bodies are subject to decay; the complex compounds of which they are composed are broken up into simpler ones, and that which was living, organized matter becomes lifeless and inorganic. This destruction of organic tissue is due under ordinary circumstances to the process called *fermentation* in some one or more forms. This is the growth and rapid multiplication of minute organisms, of which yeast is the most familiar example. When the decomposition of organic matter takes place under certain conditions and reaches a certain stage, it is called *putrefaction*. This is always attended by the multiplication of the low forms of life known as bacteria, and by the production of poisonous and ill-smelling gases. Another form of fermentation is that which occurs in the juices of fruits, grains, and vegetables which contain sugar; and is called *vinous fermentation*. In this form of decomposition the

fungus known as the *yeast plant* is the active agent in producing the changes which occur. The sugar of the fruit or plant must be in solution, and the germs of the yeast must in some way be introduced.

Alcohol is one of the products of vinous fermentation. It is composed, like sugar, of carbon, hydrogen, and oxygen, but in proportions different from their proportions in sugar. The drinks which contain alcohol differ widely in flavor according to their sources, and also vary in the amount of alcohol which appears in them. In cider and some kinds of beer the proportion may be as low as 2 per cent. As alcohol is a very volatile fluid, it may be readily separated from the other substances in the fermented liquor by the process called *distillation*. This is the driving off of the alcohol in the form of vapor by the application of heat, and its recondensation, by cooling, to liquid again. In this way is obtained the strong alcohol which is mixed with various coloring and flavoring matters to form the *spirituous liquors* of commerce. Whether a drink contains the 2 per cent of alcohol found in cider, or the 50, or more, per cent found in whisky, or the 90 per cent of "cologne spirits," the alcohol is in all cases identical in its nature and properties.

356. Properties of Alcohol. — Pure spirit, or "absolute alcohol," is a colorless, volatile liquid with a strong affinity for water, which it rapidly absorbs from the atmosphere or from any other substance containing water with which it comes in contact. Alcohol burns readily in the open air, that is, it is quickly oxidized and changed in its chemical composition. It is a powerful solvent, dissolving many substances not soluble in water. Though itself the product of fermentation, it is a preventive of putrefaction, — that is, it preserves animal tissue from decay,

— and introduced in sufficient amount into a liquid in a state of vinous fermentation it destroys the power of the yeast plant to multiply, while in smaller quantities it retards the growth of the living cells in direct proportion to its amount. When by the decomposition of sugar in vinous fermentation the amount of alcohol produced has reached 14 per cent, no further growth of the yeast takes place. That proportion of alcohol destroys the vitality of the living cells. It is thus useful as an antiseptic. Brought in contact with food elements outside the body, alcohol is found to harden them by abstracting the water which they contain, and to coagulate the albumin, which is thus rendered insoluble.

357. Is Alcohol a Food? — Alcohol contributes nothing to the formation of tissue, and cannot, therefore, be classed in the first division of foods, according to the definition given in § 289. As it is now proved that when taken into the stomach in dilute form and in small quantities it may be fully oxidized, producing energy, it must be reckoned in the second class of foods, as a force generator. For its stimulating effect it must also be included among the force regulators. It acts upon the digestive glands, causing them to pour out their special products more rapidly, and so seems sometimes to assist digestion.

But, although alcoholic drinks in very small amounts are found to come, strictly speaking, under the definition of food, in that they may and do develop or regulate force, they possess at the same time properties so peculiar and so dangerous that it is wise to exclude them wholly from our dietary, and use them, if at all, only under the advice of a skillful physician in case of illness. In certain abnormal conditions of the system, when ordinary food cannot be digested, it has sometimes been found that

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